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Bumblebee Program - Aerodynamic Data

Part I - Supersonic Flow Field, Pressure Field, and Panel Load Data for Validation of Computational Methods

G. A. Barnes and L. L. Cronvich

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Bumblebee Program - Aerodynamic Data

Part I - Supersonic Flow Field, Pressure Field, and Panel Load Data for Validation of Computational Methods

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Prepared for
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under Contract L-60036A

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CONTENTS

		Page
1.	SUMMARY	1
2.	INTRODUCTION	2
3.	SOURCE OF DATA	3
4.	TYPE OF DATA	4
5.	SOME POTENTIAL APPLICATIONS	5
6.	CONCLUDING REMARKS	7
7.	REFERENCES	7

SUMMARY

This report provides a brief description of those parts of an aerodynamics research project of the Bumblebee Program*, called Generalized Missile Study, from which wind tunnel data were assembled for Parts II, III, and IV of this series of reports. The source of the data, types presented, how the data of the three parts are related, and potential applications are discussed.

* The Bumblebee Program was a U. S. Navy Bureau of Ordnance program, started in January 1945 and directed by the Applied Physics Laboratory of The Johns Hopkins University. The principal purpose of this program was the development of guided missiles for the fleet.

INTRODUCTION

For many years, aerodynamicists have worked diligently at developing methods for predicting the flow around missile configurations at supersonic speeds. With the advent of very high speed computers this work has accelerated, particularly as the interest in higher angle-of-attack operation has grown. The present report has been prepared with the objective of making available to the research community a basic set of related experimental data which can be used to assist the theoretician in developing the physical model for the calculations and in validating the calculated results in reasonable detail over a limited Mach number regime.

The data were assembled from selected wind tunnel data and analysis reports, generated in the Aerodynamics Research effort of the Navy's Bumblebee Program which was carried out by The Johns Hopkins University Applied Physics Laboratory and its associate contractors during the early phase of that Program. The present task resulted from a survey conducted for the NASA, Langley Research Center and reported in NASA Contractor Report 145347 (Ref. 1).

The data are presented in Parts II, III, and IV of this report under the titles

Part II - Flow Fields at Mach Number 2.0 (CR-3115)
Part III - Pressure Fields at Mach Numbers 1.5 and 2.0 (CR-3116)
Part IV - Wing Loads at Mach Numbers 1.5 and 2.0. (CR-3117)

All data, both tabulated and graphical, were reproduced directly from the original documents. In some cases, these reproductions were altered slightly for the sake of clarity.

SOURCE OF DATA

The data of all three Parts of this report series were acquired as part of a fundamental research program, the Generalized Missile Study, carried out by the McDonnell Aircraft Corporation, under contract to the Applied Physics Laboratory between 1952 and 1959 (Ref. 2). The primary objectives of the program were:

1. To increase knowledge of the causes of induced rolling moments on supersonic guided missiles and to study methods for reducing the magnitude of these moments.

2. To study methods of improving the linearity of longitudinal static stability-and-control characteristics of supersonic wing-control and tail-control types of guided missiles.

The data presented in Parts II, III, and IV were obtained from tests in the wind tunnel at the Ordnance Aerophysics Laboratory (OAL), Daingerfield, Texas, designated as test series No. 289. The model (Fig. 1) consisted of a conical nose section with 30° included angle and a circular-cylindrical body of 1.37 in. (3.48 cm.) diameter, giving a total length of 18.00 in. (45.72 cm.) for the model, designated B_{14} when used without wings and B_5 when used with wings.

Three wings W_4, W_{25}, and W_{30} (Fig. 1) were used in conjunction with the B_5 body, all having the same 2 in. (5.08 cm.) chord, and with leading edge located 9.00 in. (22.86 cm.) aft of the nose of the model. The exposed spans per panel were:

Wing	Exposed Span
W_4	2.0 in. (5.08 cm.)
W_{25}	1.5 in. (3.81 cm.)
W_{30}	0.5 in. (1.27 cm.)

The cross sections were biconvex with the same 10% thickness-to-chord ratio from root to tip.

TYPE OF DATA

Part II - Flow Fields at Mach Number 2.0

All data for Part II were taken in OAL Test 289-19. The data presented in this Part describe the flow field in a plane through station (3) of the model, 15 in. (38.1 cm.) aft of the nose, where a tail stabilizer and/or control surface might be located. Flow field data for this station are given for two cases, (a) with no forward surfaces present, and (b) with the fixed W_4 panels present in an assortment of circumferential locations. The square W_4 wing panel had a chord and exposed wing span of 2 in. (5.08 cm.). By comparing the two sets of data, one can determine the effects of downwash from the wings.

The flow field data consist of ratios of local static and total pressure to free stream total pressure, local Mach number, and local flow angularity measured along several radial lines out from the body over an angle-of-attack range of 0° to 23°.

Complete flow field data as presented in Part II were not obtained at any other Mach number than 2.0 so that the effect of Mach number on flow fields cannot be assessed from these data.

In Part III, however, data are presented to show the effects of Mach number on pressure fields at the wing leading edge station.

Part III - Pressure Fields at Mach Numbers 1.5 and 2.0

The data for Part III were taken in OAL tests 289-7, -8, -10, -11, -12, and -19. These data describe the pressure fields in a plane through station (2) of the model, located 9.087 in. (23.08 cm.) aft of the nose, close to the station at which the leading edge of wing W_4 was placed for the data given in Part II. (See Fig. 1)

The pressure field data consisted of ratios of static and pitot pressure to free stream total pressure measured at several radial lines out from the body over an angle of attack range of 0° to 23°. Even though flow angularity data are not available, one can get a fair description of the

location of vortex cores and their extent by examining the distribution of pitot pressures in the plane normal to the missile axis.

Part IV - Panel Loads at Mach Numbers 1.5 and 2.0

The data for Part IV were taken in OAL tests 289-4, -11, -12, -25, and -26. The data give wing panel normal force coefficient, and chordwise and spanwise centers of pressure for three rectangular wing planforms, W_4, W_{25}, and W_{30}, attached to the B_5 body (see Fig. 1).

The tests were run primarily at two roll orientations, $\phi = 0$ and $\phi = 45°$, with both cruciform and planar arrangements of wings over an angle of attack range of 0° to 23°. The wing leading edges were located 0.087 in. (0.22 cm.) ahead of the station at which pressure fields were measured in Part III. It should be observed, however, that the presence of the wings would have affected the pressure fields had they been present in the tests of Part III.

SOME POTENTIAL APPLICATIONS

1. Flow Around an Axially Symmetric Body

The theories and computer simulations for flow fields around bare axially symmetric bodies can be validated in some detail with the complete flow field data at station (3) from Part II and with the pressure field data at station (2) in Part III.

Theories which make use of cross-flow Mach number, M_c, have, in Part III data, a considerable overlap in cross-flow Mach number since for $M = 1.5$, M_c ranges from 0 to 0.586 and for $M = 2.0$, M_c ranges from 0 to 0.781.

2. Flow Around an Axially Symmetric Body with Wings

By comparing the flow field data around the bare body at station (3) with data at that same station when cruciform wings are present (Part II data), the effect of wing downwash at the tail station can be derived. The number of wing orientations tested makes it possible to derive the downwash effects of the windward wing panels only, or the leeward wing panels only or

all four wing panels when the wings are oriented in the X position. Likewise, a comparison can be made with the downwash effects of wing panels in the horizontal orientation.

A further aid to such an analysis is the availability in Part IV of wing panel force and center of pressure data for the wing orientations of Part II.

3. Wing Loading on Body-Wing Configurations

(a) Effects of Roll Orientation

Theories which predict wing loading on a body-wing (or body-tail) configuration can be validated with the data of Part IV for both planar and cruciform configurations in non-trim (ϕ = 15°, 30°) as well as trim (ϕ = 0°, 45°) roll orientations at both M = 1.5 and 2.0.

(b) Panel-Panel Interference

Furthermore, by comparing data from the planar configuration with data from the cruciform configuration (as has been done for some cases at M = 2.0 in the Appendix of Part IV) the interference between panels can be isolated.

(c) Effect of Panel Span

Since data are given for wings of three different spans, the theoretician will have the opportunity to evaluate the predictive methods for wings of several low aspect ratios since the rectangular wing panels have aspect ratios of 1.0, 0.75, and 0.25.

(d) Effect of Wing Incidence

The data of Part IV at M = 2.0 include results of tests on planar and cruciform configurations with wing incidences at trim roll orientations. Therefore, the predictive methods can be validated for effects of wing incidence on panel loads and centers of pressure.

CONCLUDING REMARKS

Although the primary purpose of the tests providing the data for Parts II, III, and IV was the investigation of rolling moments and longitudinal stability of a generalized missile model, the study of the causes of some of the observed roll and pitch behavior led to diagnostic tests which provided data useful for other types of investigations. The variations of the parameters, however, may not appear to be as broad as now desired for these secondary investigations. Nevertheless, the data do provide an additional source for validating some of the emerging predictive methods and are presented with that purpose in mind.

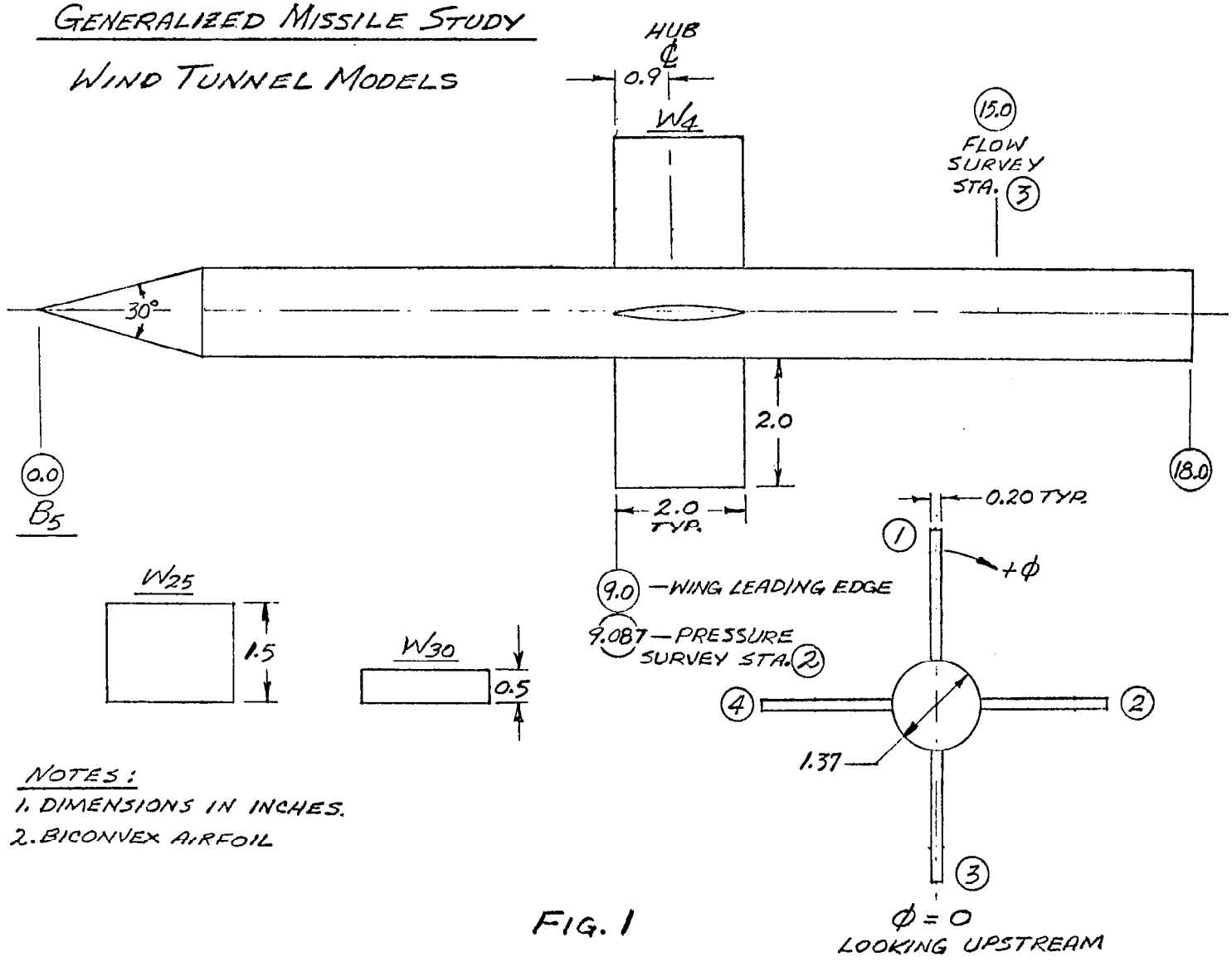
REFERENCES

1. L. L. Cronvich and G. A. Barnes, "Index for Aerodynamic Data from the Bumblebee Program," The Johns Hopkins University, Applied Physics Laboratory, NASA Contractor Report 145347, April 1978.

2. J. F. Mello, "Investigation of Normal Force Distributions and Wake Vortex Characteristics of Bodies of Revolution at Supersonic Speeds," Journal of the Aero/Space Sciences, Vol. 26, No. 3, pp. 155-168, March 1959.

GENERALIZED MISSILE STUDY

WIND TUNNEL MODELS



NOTES:
1. DIMENSIONS IN INCHES.
2. BICONVEX AIRFOIL

FIG. 1

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Topical Report

16. Abstract

The Bumblebee Program, initiated in 1945 by the U.S. Navy Bureau of Ordinance, was designed to provide a supersonic-guided missile. The Aerodynamic Program included a fundamental research effort in supersonic aerodynamics as well as a design task in developing both vehicles and prototypes of tactical missiles.

A series of four reports were prepared in order to facilitate dissemination of a large amount of fundamental aerodynamic missile data, which has been stored for a number of years at the Applied Physics Laboratory.

This report provides a brief description of those parts of an aerodynamics research project of the Bumblebee Program, called Generalized Missile Study, from which wind-tunnel data were assembled for Parts II, III, and IV of this series of reports. The source of the data, types presented, how the data of the three parts are related, and potential applications are discussed.

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